COMPARISON OF OPTIMISED TREATMENT PLANS FOR RADIOSURGERY AND CONFORMAL RADIOTHERAPY

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Abstract - **The aim of conformal radiation therapy and of radiosurgery (Gamma Knife and Multi-beam radiosurgery) is to irradiate the pathological target volume with ionising radiation while avoiding as well as possible the surrounding normal tissues. Considering the accuracy of these treatments, it is interesting to compare the different techniques to evaluate their effectiveness. This comparison involves 8 clinical cases. For each treatment modality, we compare indexes defined in the international literature by the Radiation Therapy Oncology Group (RTOG). This theoretical study shows (i) the interest of the use of intensity modulation in the case of conformal radiation therapy and (ii) the improvement of RTOG indexes with using the conformal radiotherapy although the VNT25% and the VNT50% remains better with the radiosurgery.**

Keywords - **Conformal radiation therapy, Radiosurgery, Treatment planning, Optimization,**

I. INTRODUCTION

The radiosurgery concern is the treatment of small lesions in the brain. The immobilization of the patient is obtained by a stereotactic frame. The convergence of a great number of beams in a point makes it possible to obtain an high dose and high gradient of dose, while keeping low intensity delivered by each beam. Intensity is thus distributed on a great number of beams to reduce the dose received by normal tissues and by organs at risk. Among the techniques used in radiosurgery, this work relates to two techniques : Knife Gamma and multibeam stereotactic radiosurgery.

Gamma Knife (GK) (Fig.1) uses the convergence of beams resulting from 201 radioactive sources of Cobalt 60 focused in a point: the shooting center. Each source can be blocked by a plug to avoid intersection with an organ at risk. The collimation of the beams is done using circular collimators of various diameters (4, 8, 14 and 18mm). These collimators are placed on a removable helmet fixed on the head of the patient by the way of the Leksell stereotactic frame. Generally, the helmet consists of the same size collimators.

The multibeam stereotactic radiosurgery (SRS, Fig.2) uses X-rays from the linear accelerator (LINAC). The irradiation is carried out in a continuous way following of non-coplanar arcs. These arcs are obtained thanks to the movements of the accelerator and the support of the patient (bed or seat) on whom the head of the patient is immobilized using the stereotactic frame. The collimators are circular, the diameter of which varying from 6 to 25mm by step of 2mm and one collimator of 25 mm diameter.

The conformational radiotherapy treats volumes generally larger than those of radiosurgery using 3 to 9 static fields. It also requires a high degree of accuracy for irradiation and it uses contention frames and adapted collimators which allow a high conformation to the tumour with a technique known as of beam's eye view (BEV). These multileaf collimators, fixed on the LINAC, are composed of leaves sliding the ones to the others under the remote supervision from a standard personal computer. Recently, techniques of intensity modulation (IMRT) were developed which consist in varying, for the same field, the intensity of the beam. IMRT makes it possible to obtain a better conformation of the irradiation and to minimize the dose received by normal surrounding tissues.

II. METHODOLOGY

In the case of Gamma Knife (GK), we adopted a technique which consists in fixing different collimator sizes on the same helmet. The advantage of this technique is to allow a better conformity of the dose distribution [1]. To create a treatment plan, the user specifies the number of centers of shootings and their 3-D position in order to cover the whole target volume as well as possible. The optimization of the collimator sizes, the presence or not of plugs and weightings of the intensity of each beam is obtained by simulated annealing method.

With regard to multibeam stereotactic radiosurgery, the number of isocenters is determined by the user. Their 3-D positions as well as the collimator diameters are determined by a method of conjugated gradients. The other parameters as the beam intensities, the number and the position of the arcs are obtained by a simulated annealing method [2].

Fig.1 : Gamma Knife

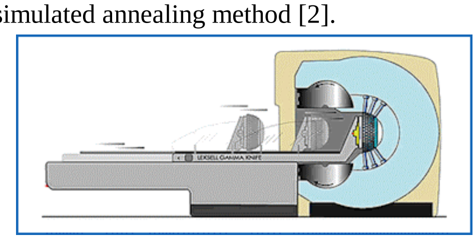
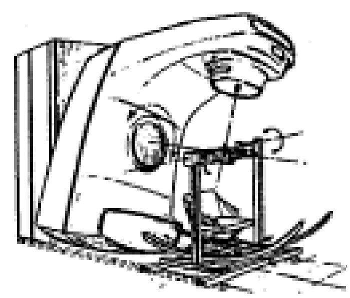


Fig.2 : LINAC and Betti's chair



For the conformational radiotherapy, the micro multileaf collimator used is the ConforMAX™ Radionics® (Fig.3). This collimator (µMLC) is composed of 31 pairs leaves

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Abstract

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(4mm width at the isocenter). The dose calculation is obtained by a method of decomposition in elementary pencil beams of 2x4mm size. For the realization of a treatment plan, the number of fields is chosen by the user, the orientations of these fields are optimized by a genetic algorithm and the other parameters (i.e. positions of the leaves, field intensities, elementary pencil beam in the case of IMRT) are given by a simulated annealing method.

Fig. 3 : Micro multileaf collimator

We compared the treatment planning optimization results of the 3 techniques on 8 clinical cases: 3 meningiomas, 3 metastases, and 2 acoustic neurinomas. For each volume, the prescribed dose is fixed at 70% with a maximum dose of 100%. The first two protocols relate to the radiosurgery with GK and SRS. The last relates to the conformational radiotherapy with the µMLC, and in this case 5 fields with IMRT are used. The comparison of the protocols is done starting from the RTOG indices [3]: HI, Ci, Co, VNT50% and VNT25%. The homogeneity index (HI) corresponds to the ratio of the maximum dose within target volume to the prescribed dose (in our case it will have to lie between 1 and 1,43). The conformity index (CI) corresponds to the ratio of volume having received a dose higher or equal to the prescribed dose to the volume of the target: the value obtained must be close to 1 as much as possible. The coverage index (Co), expressed as a percentage, represents the value of the minimal dose received on the contour of target compared to the prescribed dose. This factor must be close to 100%. The VNT25% and VNT50% are the ratio of the irradiated volumes with 25% and 50% of the maximum dose to the volume of the target ; these indices must be as low as possible.

III. RESULTS

In all the cases (Table I), the use of a low number of fields with modulation of intensity for the µMLC makes it possible to improve conformity compared to the other techniques (GK and SRS). However, considering the quantity of healthy tissue irradiated, the use of a low number of fields with µMLC does not allow to obtain VNT25% and VNT50% less or equal to those obtained with GK and SRS.

IV. DISCUSSION - CONCLUSION

The use of µMLC improves conformation. But the dose delivered to surrounding healthy tissues is weaker with the GK or SRS treatment plans. However in the case of the µMLC radiotherapy, the irradiation dose fractionation allows the regeneration of healthy tissue, and thus avoids tissue necrosis. In addition, radiosurgery techniques (GK and SRS) are very effective for the small target volumes, but they can involve an important overdosage in the case of complex and large volumes. This overdosage appears especially when numerous isocenters are used. Even if these results remain to be validated in the case of the µMLC, the comparison between the three types of treatment makes it possible to consider in certain cases substitution of usual radiosurgery by irradiation treatments carried out with an µMLC.

TABLE I
Results obtained on 8 clinical cases
(neuri: neurinoma, meta: metastasis, menin: meningioma.)

Volume	Type of treatment	CI 1.00	HI 1.00	Co 100%	VNT 50% Min.	VNT 25% Min.
Neuri2	**GK**	1.43	1.09	99.9	5.7	13.6
	SRS	1.34	1.25	100.1	3.2	16.1
	µMLC	1.17	1.07	99.9	5.2	25.5
Menin2	**GK**	1.76	1.04	99.5	5.1	11.8
	SRS	1.34	1.25	100.0	2.8	10.2
	µMLC	1.18	1.16	99.6	4.2	19.3
Menin1	**GK**	1.38	1.55	99.9	2.5	6.2
	SRS	1.35	1.31	98.9	2.5	8.7
	µMLC	1.09	1.36	99.8	3.2	11.4
Metast2	**GK**	1.47	1.34	99.8	2.3	5.2
	SRS	1.42	1.40	98.8	2.6	8.3
	µMLC	1.07	1.36	99.9	3.1	8.6
Metast1	**GK**	1.31	1.28	97.4	1.9	4.8
	SRS	1.19	1.26	99.9	2.2	7.0
	µMLC	1.03	1.41	99.6	3.0	15.5
Menin3	**GK**	1.56	2.05	86.9	2.8	7.1
	SRS	1.09	2.07	84.7	2.2	7.9
	µMLC	1.32	1.14	99.5	3.4	8.6
Meta3	**GK**	1.20	1.65	99.9	2.0	4.8
	SRS	1.53	1.14	95.9	2.9	8.0
	µMLC	1.03	1.05	99.6	2.7	7.8
Neuri1	**GK**	1.24	2.11	85.4	1.9	4.8
	SRS	1.51	1.20	99.8	3.0	9.7
	µMLC	1.08	1.33	99.7	2.9	9.8

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REFERENCES

[1] Gibon D., Rousseau J. Improved Gamma-Knife radiosurgery using combinations of different-sized collimators. Journal of Radiosurgery 1998, 1(1), 43-49.
[2] Gibon D, Rousseau J, Castelain B, Blond S, Vasseur C, Marchandise X, Treatment planning optimization by conjugate gradients and simulated annealing methods in stereotactic radiosurgery. Int J Radiation Oncology Biol Phys, 1995, 33, 201-210.
[3] Shaw E, Kline R, Gillin M, Souhami L, Hirschfeld A, Dinapoli R, Martin L. Radiation Therapy Oncology Group: Radiosurgery quality assurance quidelines. Int. J. Radiat. Oncol. Biol. Phys. 1993, 27(5), 1231-39.